Components of muscle cells

Every muscle cell contains a series of common components that are directly associated with contraction in some way, and are influenced by training. The basics are briefly described below:

The cell membrane - controls what enters and leaves the cell. Contains regulatory proteins that are influenced by hormones like epinephrine (adrenalin) and insulin. The blood concentration of these hormones greatly influences fuel utilisation by the muscle cell.
Contractile proteins - consist of actin (thick) and myosin (thin) filaments. This is the part of each muscle cell that actually produces force. All of the rest of the machinery plays a supporting or repair function.
The cytosol - the fluid medium of the cell. Provides a medium for diffusion of oxygen, ATP, etc. within the cell interior.
Mitochondria - the organelles in each muscle cell that contain oxidative enzymes and actually consume oxygen during exercise and convert the chemical energy contained in fat and carbohydrate to ATP that can be used by the cell to support contraction. Ultimately, via enzymatic processes occurring first in the cytosol and then the mitochondria, glucose and fat molecules (and certain amino acids) are broken down and combined with oxygen to form ATP, heat, carbon dioxide, and water. Each by-product has significance to the exercising athlete.
Capillaries - not actually part of the muscle cell. The capillaries physically link the muscle and the cardiovascular system. Each muscle cell may have from 3 to 6 capillaries directly associated with it, depending on fibre type and training.

Each fibre of a muscle can contribute to force production only if it is recruited by the brain. One motor nerve can branch into tens, hundreds or even a thousand branches, each one terminating on a different muscle fibre. One motor nerve plus all of the fibres that it innervates is called a motor unit. A single muscle can consist of hundreds of motor units. For example, your rectus femoris (one of the 4 quadriceps muscles) might contain 1 million muscle fibres controlled by 1,000 motor nerves. So, on average, each motor unit contains 1,000 fibres. The fibre type composition of a single motor unit will always be all one type of fibre. So a single motor unit will consist entirely of either slow twitch or fast twitch. The composition of the entire muscle will contain some combination of slow and fast motor units.

Regulation of muscular force

To regulate the force a single muscle produces, the brain combines two control mechanisms:

1. Recruitment

The motor units that make up a muscle are not recruited in a random fashion. Motor units are recruited according to the size principle.

Smaller motor units (fewer muscle fibres) have a small motor neuron and a low threshold for activation. These units are recruited first. As more force is demanded by an activity, progressively larger motor units are recruited. This has great functional significance. When requirements for force are low, but control demands are high (writing, playing the piano), the ability to recruit only a few muscle fibres gives the possibility of fine control. As more force is needed, the impact of each new motor unit on total force production becomes greater. It is also important to know that the smaller motor units are generally slow units, while the larger motor units are composed of fast twitch fibres.

2. Rate coding

Within a given motor unit, there is a range of firing frequencies. Slow units operate at a lower frequency range than faster units. Within that range, the force generated by a motor unit increases with increasing firing frequency. If an action potential reaches a muscle fibre before it has completely relaxed from a previous impulse, then force summation will occur. By this method, firing frequency affects muscular force generated by each motor unit.

Firing pattern

View the video of a tennis serve: the muscle firing pattern changes as the intensity of the action changes.

If we relate firing pattern to exercise intensity, we see this pattern. At low exercise intensities, like walking or slow running, slow-twitch fibres are selectively utilised because they have the lowest threshold for recruitment. If we suddenly increase the pace to a sprint, the larger fast units will be recruited. In general, as the intensity of exercise increases in any muscle, the contribution of the fast fibres will increase.

For the muscle, intensity translates to force per contraction and contraction frequency per minute. Motor unit recruitment is regulated by required force. In the unfatigued muscle, a sufficient number of motor units will be recruited to supply the desired force. Initially, desired force may be accomplished with little or no involvement of fast motor units. However, as slow units become fatigued and fail to produce force, fast units will be recruited as the brain attempts to maintain desired force production by recruiting more motor units. Consequently, the same force production in fatigued muscle will require a greater number of motor units. This additional recruitment brings in fast, fatigable motor units. Consequently, fatigue will be accelerated toward the end of long or severe bouts, due to the increased

lactate produced by the late recruitment of fast units.

Specific athletic groups may differ in the control of the motor units. Top athletes in the explosive sports like Olympic weightlifting or the high jump appear to have the ability to recruit nearly all of their motor units in a simultaneous or synchronous fashion. In contrast, the firing pattern of endurance athletes becomes more asynchronous. During continuous contractions, some units are firing while others recover, providing a built-in recovery period. Initial gains in strength associated with a weight-training program are due to improved recruitment, not muscle hypertrophy (increase in size).

Joint actions

Make sure you understand the following terms:

flexion
extension
abductions
circumduction
rotation
plantar flexion
dorsi flexion
supination
pronation

Movement	Definition/Example
Flexion	Involves decreasing the angle between two bones, e.g. bending the elbow or leg
Extension	Increasing the angle between two bones, e.g. bending backwards at the trunk
Abduction	Moving body parts away from the body's midline
Adduction	Moving bones towards the body's midline
Pronation	Turning the hand to have it palm downwards (radius and ulna are crossed)
Supination	Palms facing upwards (radius and ulna are uncrossed and parallel)
Inversion	Moving the sole of the foot inwards at the ankle
Eversion	Moving the sole of the foot outwards at the ankle
Dorsiflexion	Pointing the toes upwards towards the tibia
Plantar flexion	Pointing the toes away from the tibia
Circumduction	Moving the end of a bone so that it makes a circle
Rotation	Moving the bone around a central axis

Major Muscle Groups and the Microscopic Structure of Muscle

This resource:

provides an understanding of muscle action fibre types and their influence on activities
Identifyies characteristics of fast and slow twitch muscle fibres.
provides an understanding of the significance of fibre types on performance in different activities.
provides an understanding of microscopic structure, sliding filament theory; agonist/antagonist relationship; joint actions (flexion/extension, etc.); contraction types (eccentric/concentric/isometric)

Summary of muscles and their actions

Major muscles in the human body.
There are three types of muscles in the body:

smooth (intestinal wall and arteries)
cardiac
skeletal
Skeletal muscles are labelled according to the way the muscle fibres lie with respect to the tendon.

Fusiform muscles

Fibres run in the same direction as the tendon. There aren't a great number of these muscle types because they only produce low muscle force. However, they have great contractile range and so are found in muscles that require a great range of movement (e.g. gracilis muscle).

Penniform muscles

In these muscles, the fibres run at an angle to the tendon. They make up 75% of all the skeletal muscles in the body. They produce great force, but don't have great range.

There are three types of penniform muscles:

unipenate - branch to one side only (e.g. Semimembranosus)
bipenate - branch both sides of the tendon (e.g. Rectus Femoris)
multipenate - branch repeatedly (e.g. deltoid)

Types of skeletal muscle

Muscle fibre types

There are two types of muscle fibres. Each has unique characteristics:

Fast twitch (white) fibres

These fibres are associated with explosive activities requiring speed and power.

They produce a great deal of force; however, they fatigue more rapidly than slow twitch.

View the video on sprinting, which depends on fast-twitch fibres.

Slow twitch (red) fibres

These fibres are smaller than their FT counterparts and are best suited to aerobic activities. They are associated with oxygen, hence the term "red" fibres. All muscles have a percentage of both types of fibres. This is genetically determined to a large extent.

For example, distance runners typically may have:

79% ST fibres

21% FT fibres

100 metre sprinters may have:

75% FT fibres

25% ST fibres